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(54) Abstract Title
Responsive load system

(57) A responsive load apparatus is connected to a load (1) which consumes intermittent or variable energy e.g. refrigerator, air-conditioning or water heater. The responsive load apparatus (7) controls the power consumed by the load by sensing a variable associated with the load e.g. temperature, and also the frequency of the mains power supply (4). In this way the mains power supply network is better able to respond to sudden changes in demand as the responsive load apparatus switches distributed loads on or off accordingly. A control signal to set the apparatus to an active or inactive mode may be provided. The control signal may be a radio signal.

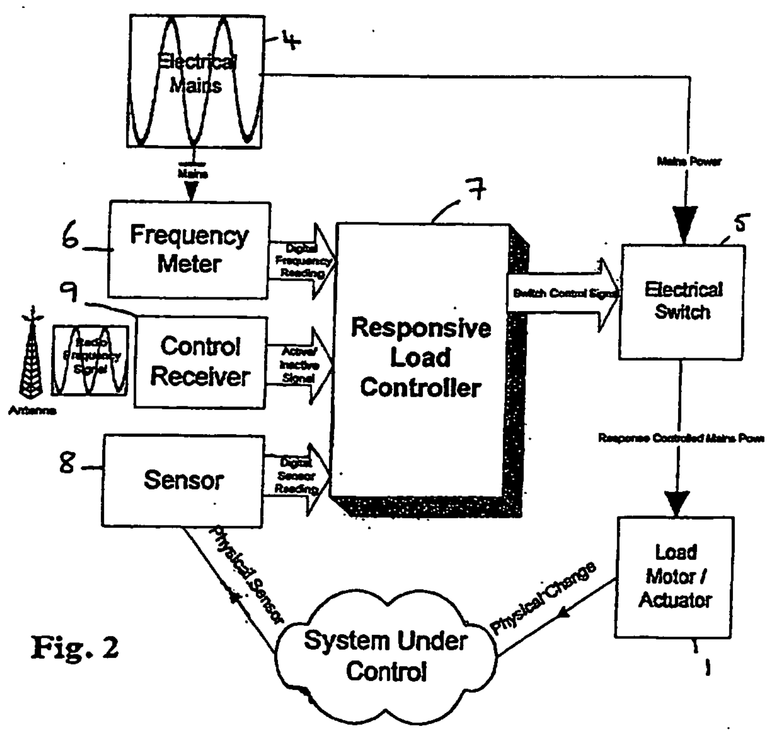

Fig. 2

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At least one drawing originally filed was informal and the print reproduced here is taken from a later filed formal copy.

The claims were filed later than the filing date but within the period prescribed by Rule 25(1) of the Patents Rules 1995.

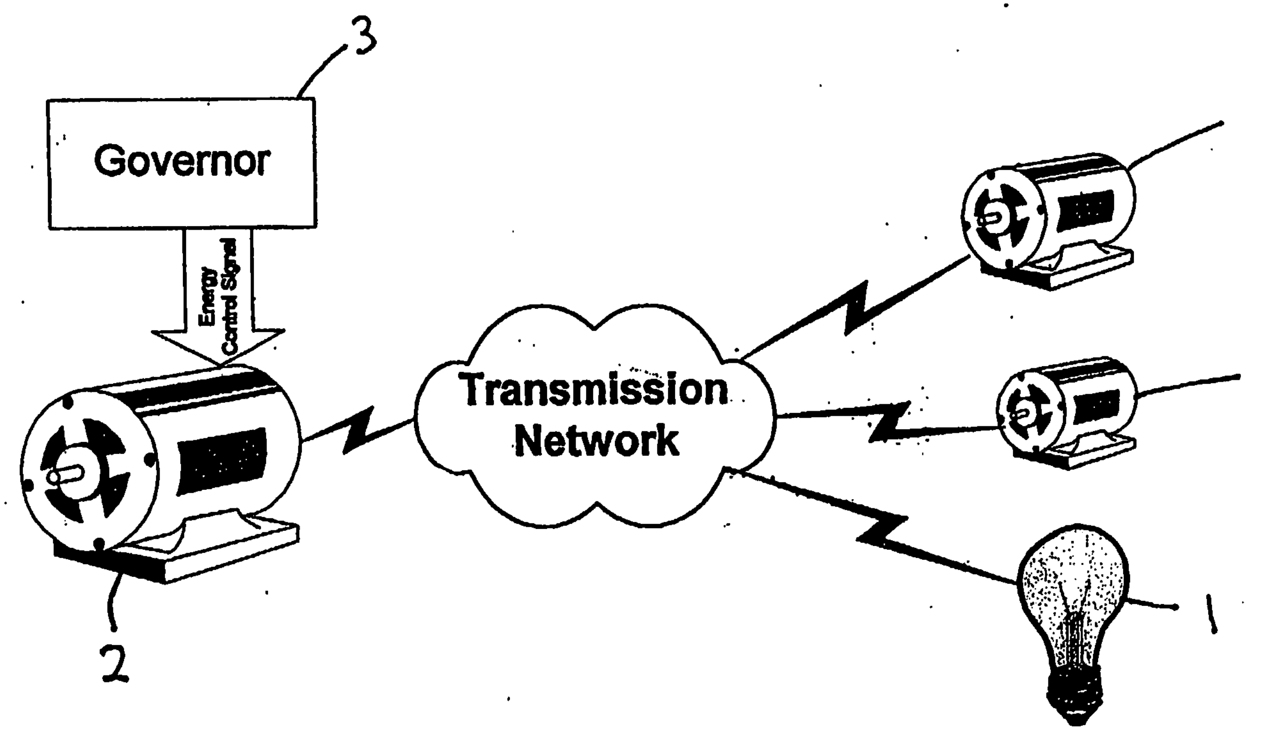
3
Governor
Energy Control Signal
Transmission Network
2
1
1
1

Fig. 1

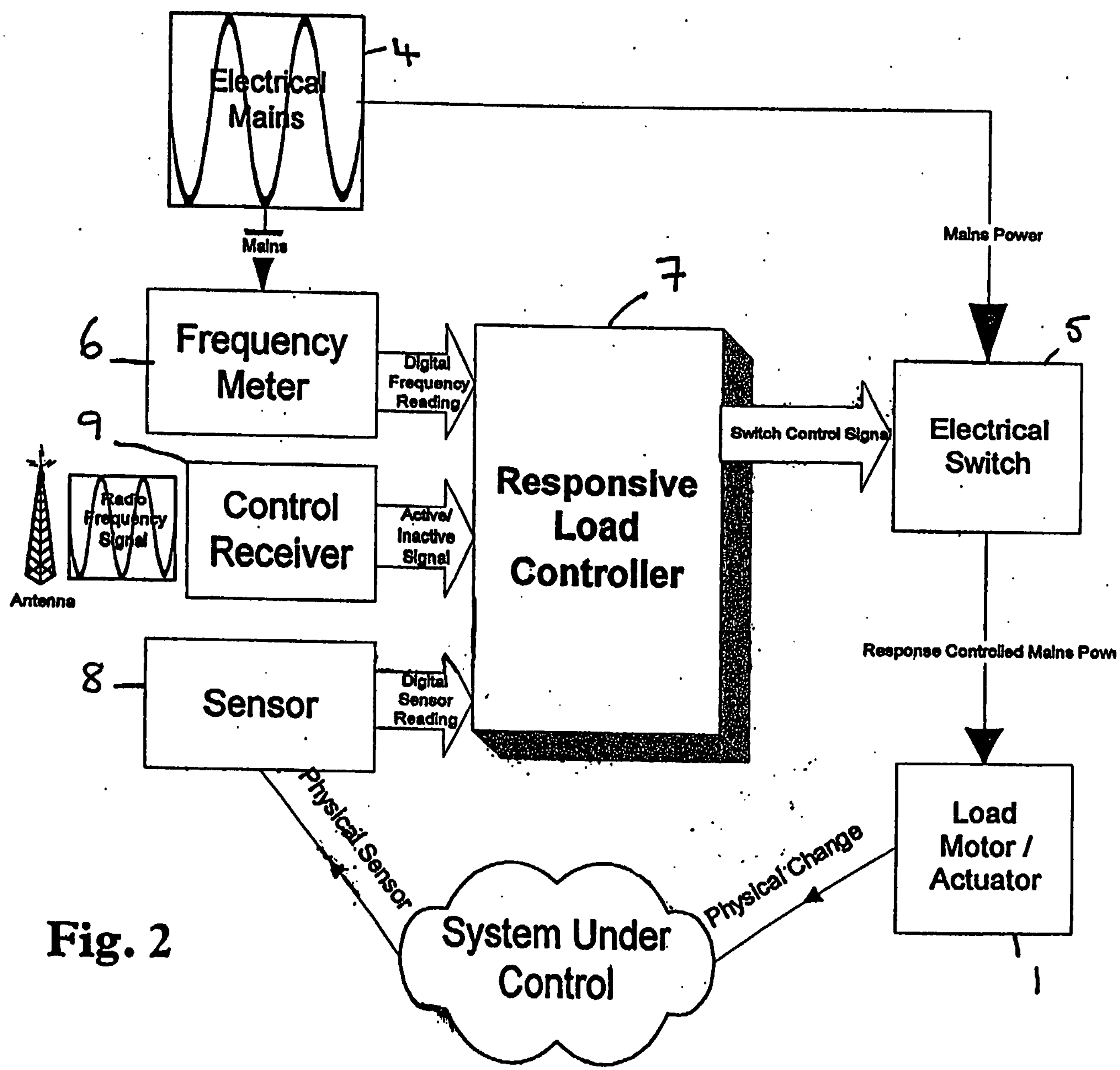
Electrical Mains
4
Mains
Mains Power
Frequency Meter
6
Digital Frequency Reading
7
Responsive Load Controller
Switch Control Signa
Electrical Switch
5
9
Control Receiver
Radio Frequency Signal
Antenna
Active/ Inactive Signal
Response Controlled Mains Pow
Sensor
8
Digital Sensor Reading
Load Motor / Actuator
1
Physical Sensor
System Under Control
Physical Change

Fig. 2

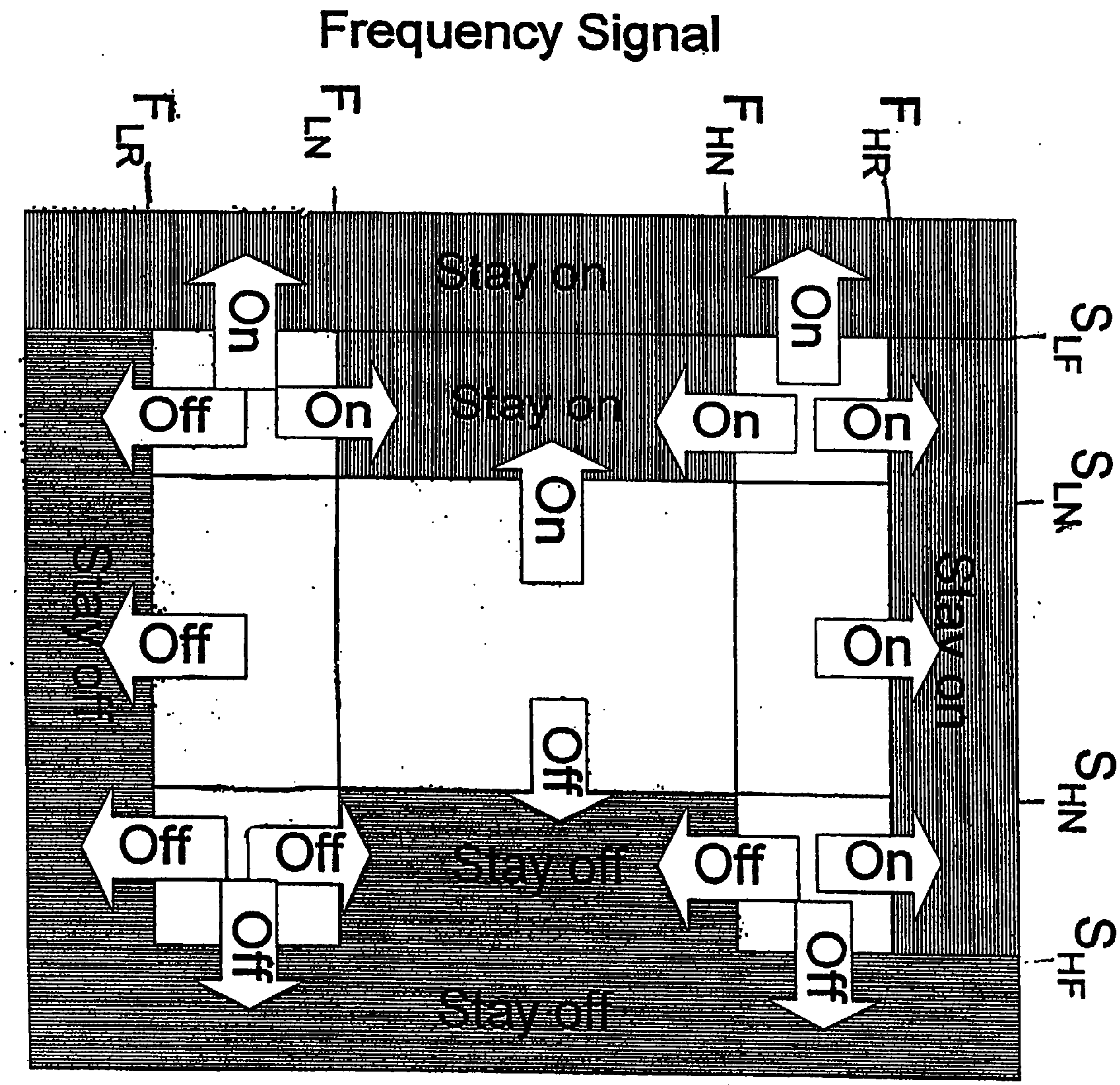
Frequency Signal
F_{LR}
F_{LN}
F_{HN}
F_{HR}
S_{LF}
S_{LN}
S_{HN}
S_{HF}
Stay on
Stay on
Stay on
Stay off
Stay off
Stay off
On
Off

Fig. 3

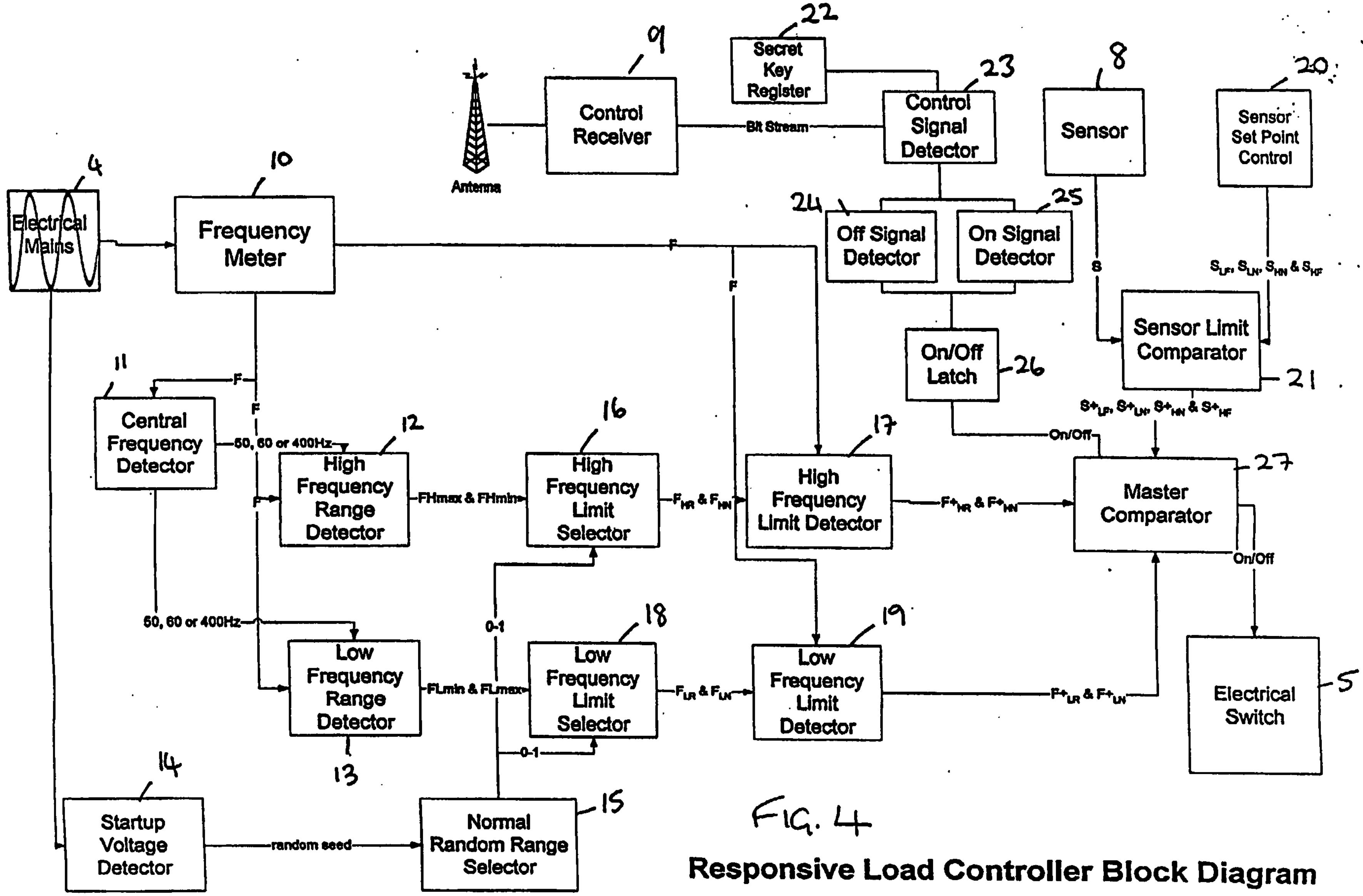

FIG. 4

Responsive Load Controller Block Diagram

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RESPONSIVE LOAD SYSTEM

The present invention relates to a device and method for controlling an apparatus which consumes mains electric power to be responsive to changes in demand on the mains supply.

It is important that alternating current (AC) electricity supply systems remain stable even when the load on the system changes or when failures occur within the system. This requires that the electrical energy input to the system very closely matches the energy being taken off or lost from the system. If this energy balance is not exact, the frequency of the system as a whole changes and the effects of the frequency changes can be seen across the whole system.

If too much power is being taken from the system, with respect to the energy input, then the system frequency drops. Conversely, if too much energy is being put onto the system, compared to the actual demand, the overall system frequency rises.

The nominal frequency in the UK and Europe is 50 Hertz, with a notional permitted deviation from this frequency of 1% (i. e. 0.5Hz). Electric energy generating plant is governed to vary the energy despatched in response to changes in the system frequency. In other countries, for example in North America, the nominal frequency is 60Hz. Some closed systems, such as aircraft, etc., sometimes use 400Hz.

To retain stability in the system as a whole, plant must be provided to respond automatically, and within a few seconds, with despatch energy essentially equivalent to the largest credible loss of generation (normally the largest single power unit running). In actual fact, the energy despatched must also take into account the behaviour of the synchronous load, the behaviour of the generation plant and the total load on the system, which all influence the need for response.

The system also has to cope with short term surges in power demand which may occur, for example, after shared national events, such as an important football match etc. Ensuring adequate response, in such events, often involves running, for a large part of the time, partially loaded (and therefore less efficient) generating plant. Hydro generation plant is often better able to quickly respond than thermal (coal or nuclear) plant. However, some countries, including England and Wales, have no natural hydro power.

Furthermore, should demand for supply unexpectedly drop, e. g. due to a transmission or distribution system fault, the system needs to have available governed plant which can reduce its input to the system, so as to avoid an increase in the overall system frequency.

Ensuring that this response capacity is available is of major concern to despatch engineers and is a major complication in the overall running of electrical supply systems involving multiple participants.

The frequency of the system as a whole is influenced by the overall mix of generation and load on the system. Much of the load is 'resistive', e. g. electrical lights, with the load varying according to the voltage at the point of the load. These types of load do not respond directly to changes in the frequency of the system, unless those changes also involve voltage changes.

The system will also have load which is 'synchronous', e. g. electric motors whose speed is locked to the frequency of the system as a whole. When the frequency of the system drops, much of this load actually reduces the energy it consumes, because it goes slower. Thus, the system, when heavily loaded, has an innate ability to respond to demand and, thus, frequency changes, in a useful way.

However, the power generators also have an innate tendency to reduce their output when the frequency of

the system drops. This can, therefore, lead to a vicious circle and, unless corrected, leads to unstable operation.

Methods of monitoring this tendency are known, but the conditions associated with this monitoring can be onerous.

Generators normally have governors which monitor the speed of the generator, and thus the frequency of the system, and vary the energy input according to the frequency. For the governors to be effective, the generators must have the capability to increase or decrease their output, i. e. they must have 'headroom'.

Headroom to **increase** capacity involves generating capacity that it usually unused and this implies less efficient running of the generator. Headroom to reduce energy is less of a problem, but problems can arise when demand is very low and the baseload plant is already running at minimum capacity.

To retain stability, the system as a whole needs plant which is able to respond automatically with additional despatch energy essentially equivalent to the largest credible loss of generation (in reality, actually taking into account factors such as the behaviour of the synchronous load, the behaviour of the generation plant and the total load on the system). The largest credible loss of generation is usually considered to be the largest single power unit running. In England and Wales, this is normally Sizewell B at 1.2 GW, but the French Interconnector is also two inputs of 1 GW each. This additional energy must be available before the frequency actually drops below the control limit. In the UK, inertia in the power supply system gives about 10 seconds before limits are breached. Major loss scenarios are considered exceptional, and it is considered acceptable to range beyond the normal 1% frequency deviation limit.

To protect the system when it is under stress,

parts of the system have automatic trips that progressively, and indiscriminately, disconnect parts of the system load as the frequency drops. Load shedding usually starts automatically before the system frequency drops below 48.5Hz.

As mentioned above, Hydro generation plant is often better able to respond than thermal plant. However, countries such as England and Wales have no natural hydro power and the capacity of the pumped storage plant is adequate only for some loss scenarios.

Ensuring that this capacity is available is extremely important and is a major consideration and complication in the overall running of the electric supply system. This concern is normally met by holding contracts to pay generators to have governors and to switch them on when requested, or by scheduling plant to be only partially loaded.

However, both of these approaches require central control of the system and the costs involved are not necessarily easily separated from other costs of controlling the system. Furthermore, these arrangements are not particularly efficient.

The aim of the present invention is to provide a response to changes in the load on the electric supply system in a simple, low cost and efficient, yet acceptable and safe way.

Accordingly, the present invention, in one aspect, provides a responsive load control apparatus adapted to be connected to an electric load which consumes intermittent or variable electric energy in order to maintain a variable within controlled limits; the responsive load control device controlling the power consumed by the load in response to the frequency of the mains power supplied to the system and the value of said variable.

According to another aspect of the invention, there is provided a method of responding to frequency

variations in a power supply system, said method involving monitoring the frequency of the system and comparing this with predetermined upper and lower frequency thresholds; monitoring a parameter of an electric load which consumes intermittent or variable electric energy in order to maintain said parameter within control limits and comparing said measured parameter with predetermined upper and lower parameter thresholds; and controlling the power consumed by said load when said system frequency is outside of the range defined by said upper and lower frequency thresholds and said parameter is within the range defined by said upper and lower parameter thresholds.

Preferably, the device includes means for detecting the frequency of the mains supply and means for detecting the value of the variable of said load and means for comparing the detected frequency with predetermined upper and lower frequency thresholds; and means for comparing said variable with predetermined upper and lower thresholds, and means for switching off or reducing power supply to the load when said system frequency drops below said lower frequency limit, and said variable is within the range defined by the upper and lower thresholds, and means for switching on or increasing power supplied to the load when said frequency is above the upper frequency limit and said variable is within the range defined by the upper and lower thresholds.

Preferably, the device includes sensing and analysis means adapted to automatically optimise or adjust the predetermined threshold values in response to recent recorded behaviour of the overall mains supply system. This allows the responsive load control device to be self-adjusting.

Whilst the device can be continually operable in a responsive manner, means may be provided to switch the responsive load control device on or off. The device

may include a radio data demodulator and decoder, to allow populations of such devices to be switched on or off, thus ensuring that investors in the device can continue to be rewarded for their investment.

Preferably, when a radio signal is used for switching the devices on or off, the switching should be protected from unauthorised commands by means of encryption. This protects the system against, e. g., extortion by 'cyber attack'.

Control mechanisms may also be provided to enable those in control of the responsive load device or devices to adjust the volume of response. This allows the users to actively participate in a market for response. These control mechanisms preferably include protection to prevent unauthorised control of the devices.

Embodiments of the invention will now be described, by way of example only, with reference to the accompanying drawings.

Fig. 1 shows some common components of the AC electrical supply system;

Fig. 2 shows a block diagram of the responsive load control system of the present invention;

Fig. 3 shows a control actions diagram showing how the responsive load control device of the invention operates; and

Fig. 4 shows a block diagram of a responsive load control device according to the present invention.

As stated above, the frequency of the system as a whole is influenced by the overall mix of generation and load on the system. Much of the load 1 is 'resistive' like electric lights. Other consumers are 'synchronous' such as electric motors. Generators 2 which provide electrical energy to the network normally have governors 3 which monitor the speed of the generator 2 and, thus, the frequency of the system and vary the energy input, according to frequency.

Fig. 2 shows how a responsive load controller according to the present invention could be incorporated into the electric energy supply system. Mains electricity is supplied to the system, from the electrical supply network 4. Mains power is provided to the loads 1, e. g. via an electrical switch 5. A signal from the mains is also provided to a frequency meter 6 which outputs a signal, in this example a digital signal, indicating the frequency of the mains power, and thus the system as a whole. This signal is provided to the responsive load controller 7.

The responsive load controller is adapted to be connected to or built into a device which consumes intermittent or varying power from the mains supply. An example of such a device is a refrigerator which has a compressor that starts when the temperature of the cooled space rises above a particular limit and which stops when the temperature reaches a lower limit. Thus, power is consumed from the system to maintain an internal variable, in the case of the refrigerator, the interior temperature, within controlled limits. The refrigerator is but one example of such a device and there are many other large and small devices which consume intermittent load in this way, to maintain an internal variable within controlled limits.

A sensor 8 is also provided, in association with the device being controlled, to detect and provide a signal indicative of the value of the parameter being controlled, e. g. the temperature of the interior space, in a refrigerator or an air-conditioning system. In other appliances or applications this parameter or characteristic may be a water temperature, a water level or some other variable that can be controlled by varying the consumption of power. Any available type of sensor may be used, which can detect the characteristic or parameter in question and provide a signal indicative of its value or level. This signal is input to the

responsive load controller 7 e. g. as a digital signal.

A control signal may also, optionally, be input to the controller, to set the responsive load device in an active or inactive mode. This signal may be provided by a control receiver 9 which monitors predefined radio frequencies for modulated control signals that it can decrypt. On successful decryption and appropriate confirmation, the control receiver will drive the active/inactive signal appropriately. Alternatively, a simple on-off switch may be used or some other means for providing an active/inactive signal to the controller. Alternatively, the responsive load controller may be permanently on or active.

Based on the input mains system frequency and the sensor signal and, if appropriate, the active/inactive signal, the responsive load controller provides a switch control signal to control the load and its power consumption, based on the signals input to the responsive load controller. The switch control signal may be provided to a simple on-off switch, appropriate to switching the size of load. Alternatively, it may be a device that can vary the load continuously or in discrete steps, for example.

The load consumes power to achieve the objective of the appliance and to influence the system under control, by taking into account the frequency of the mains system. For example, in a refrigerator or air conditioner, the power would be consumed to influence the compressor motor. In, for example, a tank replenishment system, the pump would be controlled. In, for example, a battery replenishment system, the battery charging circuit would be controlled.

Fig. 3 shows how the responsive load controller processes and uses the input frequency and sensor signals to control the power consumed by the load in a system responsive manner.

The horizontally shaded portions in Fig. 3 show the

conditions where the load will be on. The vertically shaded portions show conditions where the load will be off. In the unshaded portions, the output will not change, i. e. if the output is already on, it will stay on and if off, it will stay off.

From the diagram of Fig. 3, it will be seen that when the mains frequency is within pre-determined 'regulated' limits, the device behaves precisely as an ordinary control device, controlling the system to stay within the prescribed limits. I. e., in the case of a refrigerator, for example, when the temperature drops below a predetermined, normal, threshold, the compressor is controlled to consume power from the system. If the internal temperature exceeds a predetermined normal threshold, the compressor is switched off.

When the sensor value is outside widened parameter limits (S_{LF}-S_{HF}), the system is controlled to bring the parameter back within the prescribed normal limits (S_{LN}-S_{HN}) as quickly as possible, regardless of the frequency of the system. This is a safety feature which protects the consumer in the event of unusual conditions, or during recovery after some excursion.

The rest of the diagram of Fig. 3 shows the novel responsive load operation.

When the sensed parameter is within the widened range (S_{LF}-S_{HF}) and the frequency drops below the lower regulated frequency limit (F_{LR}), the load will switch off or, if already off, will stay off.

When the frequency rises above the higher regulated frequency (F_{HR}) and the sensed parameter value is within the widened limits, the load will switch on (or, if already on, stay on).

I. e., so long as the sensed parameter is within the wider 'safety' range, the device controls the load in a responsive manner, i. e. responsive to changes in the system frequency and, hence, responsive to changes in demand on the system. E. g., with the 'safety'

limits, when the system frequency drops below a preset limit, the responsive controller causes the load to, in this embodiment, switch off, even if the sensed parameter is actually higher than the threshold which would, under normal control, cause the load to switch off.

After taking frequency control action, i. e. controlling the load when the sensed parameter values are within the widened range limits, and when the system frequency occurs outside the regulated frequency limit, the responsive controller will allow the frequency to move within narrower limits (F_{LN}-F_{HN}) before reverting to its normal control mode.

The effect of a population of devices controlled in this way is to temporarily reduce load when the system frequency drops below limits, and to temporarily increase load when the frequency rises above limits. With appropriate control limits, the effect is to stabilise the frequency of the electricity system as a whole.

Thus, the system as a whole becomes more stable and better able to cope with variations and failures. Furthermore, generation plant can be run more efficiently by avoiding the inefficiencies of part loading and the operation of governors.

Other benefits are that participation in a system by generators and by others need not be so closely controlled by a central agency and the monopoly power of generators in provision of response is reduced - the 'demand side' can participate in providing response.

This also allows the complexity of generator controls to be reduced and very large generating units can be introduced, without associated increases in the volume of generation response required.

Further, the system is better able to cope with changes in the uses of power, in particular the increasing use of active control devices which are

presently reducing the innate response of the system.

The embodiment described above, with respect to Fig. 3, operates at two levels, i. e. off and on. In an alternative embodiment, a controller of a switch with multiple discrete load steps or continuously variable load can be used. Instead of merely switching the load on or off, this would vary the load according to a height that varies in discrete steps, or continuously, across the control surface defined within the controller. This device may also have a timing component to avoid hunting between control states.

If an active/inactive signal is used as an input to the controller, and the controller is set to be inactive, the normal sensor thresholds are set equal to the narrowed (or widened) limits, thus inactivating the responsive load elements of the controller and causing the controlled load to act in its normal way.

The sensor limits (S_{LF}, S_{LN}, S_{HN}, S_{HF}) are chosen to match the requirements of the appliance under control and can be varied in the same way as a normal set point controller. In a refrigerator, for example, they are derived from the thermostat control.

The difference between the normal and frequency responsive limits are derived such that the load is responsive for a reasonable portion of the time. For low frequency response, this is part of the 'duty cycle' of the device during which it would normally be on. In general, this is 25% - 50% of the time. Furthermore, the difference between the normal and frequency responsive limit is set so that the device will stay off, or stay on, when being frequency responsive, for a reasonable period of time. In general, this will be around 10 to 15 minutes, when there is no disturbance to the appliance, such as the refrigerator door being opened.

Clearly, the more responsive the appliance is to changes in frequency, and, thus changes in demand on the

overall supply system, the greater its value to the system.

The frequency limits (F_{LR}, F_{LN}, F_{HN}, F_{HR}) are preferably chosen so that a population of responsive devices will progressively respond in a precisely controlled way, as excursions from the nominal frequency become greater.

The optimum scheme for selection of the frequency limit distributions, which need not be the same for low and high frequency excursions, will depend on the most desired characteristics for control of the particular electricity system to which the population of devices is connected, and may change as the number of devices and the overall characteristics of the network change.

Preferably, the frequency limit distributions are selected such that the extent of the deviation from the nominal frequency gives a monotonically increasing, and, ideally, linear, indication of the volume of energy necessary to restore the system to balance.

Preferably, the response should be all 'used up' at the point when the frequency has reached other control limits and other reserve needs to be brought in.

The control limits may have a skewed normal distribution, or similar, to achieve this in ways which match the available reserve.

The limits for a particular device should preferably reflect the 'duty cycle' of the device. The high and low frequency responses should reflect the different needs and value for the different types of responses.

The nominal frequency or central frequency may be chosen by monitoring the frequency of the mains when the device is first switched on and selecting as a central frequency whichever standard frequency is closest to the detected signal (e. g. 50Hz, 60Hz or 400Hz).

There are various ways in which the frequency limits for each particular device, may be arrived at.

Appropriately distributed limits may be pre-programmed into the population of devices to be connected to the system. Thus, a particular device will have response characteristics that are static over time, but different devices will have different limits.

Alternatively, probabilistic techniques can be used, so that an individual device has its limits set by statistically random selection from a distribution of limits within a range. The statistically random selection ensures that a population of devices matches the overall distribution required.

This ensures that any disadvantage associated with having a responsive device is distributed across the population of devices.

The parameters of the randomisation may be adjusted in the light of the variation of the frequency over a given period. For example, the highest and lowest system frequencies may be recorded for every hour, or some other measurement period. Each day, for example, the most recent extremes for the most recent measurement period may be compared with extremes for the equivalent measurement period recorded in earlier days.

If the extremes are greater, the historical extreme may then be increased by a proportion of the difference. This proportion is chosen as a parameter which may be different for upper and lower frequency limits. The proportion chosen may be a more complex function of previous frequency measurement using proportional, integral and derivative (PID) control techniques. For example, a simple proportional figure of 0.25 on daily limits is a figure that will adjust the limit in the experience of the past week or so.

If the extremes are smaller for the day of measurement, the historical extreme may then be reduced by a proportion of the difference. As with increasing extremes, the parameter sets the amount by which the limits will change.

There may be separate limits for every hour, or other such measurement period, of the day. There is no need for clocks within different devices to be synchronised with each other, or with any central control points, as the devices will each optimise for the measurement periods as they choose them.

Following a power failure, all of the hourly (or measurement period) limits would be set to the average.

Preferably, the device will continue to provide response for as long as the controlled device is in use. This essentially means that the response service provided would have been paid for at the time of installation of the responsive load controller and would, in effect, be a capital purchase or long term contract agreement by a representative of the system as a whole.

However, there may not be such a representative available or willing to pay an appropriate fee. If, for example, the representative was franchised for a limited period, and the representative changed, the incoming representative would have no incentive to pay for the ongoing service of response and yet would continue to receive the benefit.

Thus, the control device may optionally include a control receiver which monitors one or more radio frequency signals. These may be signals such as the BBC 198 kHz long wave transmission signal which includes a digital control signal in its modulation; the short range digital control signals known as 'BlueTooth'; modulations of Global Positioning System signals or similar satellite transmission signals (e. g. Geodesic or Iridium); or signals designed for communication with meters and used by a population of meter readers.

The control receivers would be preloaded with a range of internal identifiers, secret to the authority controlling the devices. These identifiers would act as keys to decrypt incoming signals in such a way that only

the controlling authority could construct a signal that would be recognised by the device. The number of devices that would recognise a particular signal would depend upon the nature and need of the forecast market for response, and on the coverage of the broadcast signal monitored. It is anticipated that a BBC long wave signal would activate or deactivate a few 10s of MW of response.

The need to encrypt the signal in this way arises from the possibility that, if responsive load devices were not protected in this way, an electricity system could be destabilised by a hostile broadcast of a signal that deactivated a large volume of response.

As mentioned above, the responsive load control device of the present invention may be used with any device that consumes intermittent or variable electric energy to maintain a variable within controlled limits. Such devices include, without limitation, domestic and industrial refrigerators and deep-freezers; air conditioning units in domestic, commercial and industrial applications, pumps for pump storage systems, including water and other supply tanks; electric heaters, e. g. domestic immersion heaters, heaters in washing machines and dishwashers; or storage heaters (although these would be useful only during particular periods of the day).

The responsive load controller may be in the form of a Programmable Logic Controller (PLC) programmed to operate in the manner described. The controller can, however, also be built using discrete logic or built in a simple integrated circuit.

Fig. 4 shows, in block diagram form, one example of a responsive load control device which can operate in accordance with the present invention.

The circuitry includes a frequency meter 10 which produces a signal proportional to the measured frequency of the mains, which is input to the control device.

A central frequency detector 11 produces a central frequency signal indicating the essential or nominal frequency that the controller is aiming to support. This preferably creates a signal from standard 50Hz, 60Hz or 400Hz frequencies, selecting that which is closest to the detected frequency, when the load is switched on.

A high frequency range detector 12 processes the incoming frequency of the system over a set of sample periods, to derive the range of frequency above the central frequency, over which the controller is to be active. The output is a maximum frequency at which high frequency control will always have been attempted, and a minimum frequency below which high frequency control will never be attempted.

A low frequency range detector 13 processes the incoming frequency over a set of sample periods to derive the range of frequencies below the central frequency over which the controller is to be active. The output is a minimum frequency at which low frequency control will always have been attempted, and a maximum frequency above which low frequency control will never be attempted.

A startup voltage detector 14 measures the voltage at the instant the device is first switched on. This is not related to any fixed parameters and is effectively uncontrollable. It is, therefore, a reasonably reliable source of a random signal which can act as a trigger to a random range selector.

A normal random range selector 15 creates a random signal, within the logic range 0-1, distributed according to, for example, the normal distribution or some other similar statistical distribution. Fig. 4 shows a single random range selector. However, it may be more appropriate to have two, one for high and one for low, with different distributions, or with different skewing of the normal distribution.

A high frequency limit selector 16 processes the minimum or maximum frequency values and the random signal to produce the control limits F_{HR} and F_{HN}. This ensures that the limits set in a population of devices will be distributed to maximise the control benefit.

A high frequency limit detector 17 compares the incoming frequency to the control limits F_{HR} and F_{HN} to produce respective logic signals indicating when the respective limits have been exceeded.

A low frequency limit detector 18 processes the low frequency limit signals and the random signal to produce the control limits F_{LR} and F_{LN}. This ensures that the limits set in a population of devices will be distributed to maximise the control benefit.

A low frequency limit detector 19 compares the incoming frequency to these lower control limits to produce respective logic signals indicating respectively when these lower limits have been exceeded.

A sensor 8 detects the level of the parameter the system is intended to control.

A sensor setpoint control 20 is used to adjust the central point around which the controller is to control, and form the parameter limit signals S_{LF}, S_{LN}, S_{HN} and S_{HF}.

A sensor limit comparator 21 takes these sensor limit signals and compares them with the actual sensor signal to produce logic signals indicating respectively when the various limit signals have been exceeded.

A control receiver 9 demodulates the chosen control channel to produce a potential signal bit stream.

A secret key register 22 holds a key secret to the owner or authorised operator of the device.

A control signal detector 23 scans the incoming bit stream for a sequence that indicates the transmission of control sequence to the device. The incoming bit stream is compared to the secret key so that only properly authenticated signals will be passed on.

An on signal detector 24 and an off signal detector

25 note the nature of an authenticated incoming signal.

An on/off latch 26 ensures that the last authorised control signal will be retained and used.

A master comparator 27 performs logic operations to compare the incoming logic signals indicating whether the frequency and on/off latch sensor limit signals have been exceeded and produces an on/off signal.

An electric switch 5 is provided for switching the load on or off.

Thus, as described above, the responsive load controller may be used within a device which consumes intermittent load or variable load from the mains system in order to maintain an internal variable within controlled limits. With a population of devices controlled in this way, using appropriate control limits, the frequency of the system as a whole can be stabilised, providing the benefits discussed above. With this device, the consumer can participate in and exercise some control over the response of the system which provides the advantage that when demand on the systems is high, the system response is not indiscriminate, but optimised according to the value of response and the importance of power supply to consumers, as determined by them. The effect of the responsive load control is a slightly wider range over which the controlled variable may range, and the 'consumer end' can decide whether this is acceptable, according to the nature of the device.

CLAIMS

1. A responsive load apparatus adapted to be connected to an electric load which consumes intermittent or variable electric energy in order to maintain a variable within controlled limits; the responsive load control device comprising means for controlling the power consumed by the load in response to the frequency of the mains power supplied to the system and the value of said variable.

2. An apparatus as claimed in claim 1 further comprising:

means for detecting the frequency of mains power supplied to the system and means for detecting the value of the variable of said load; and wherein said means for controlling the power consumed comprises means for comparing the detected frequency with predetermined upper and lower frequency thresholds, means for comparing said variable with predetermined upper and lower thresholds, and means for switching off or reducing power supply to the load when said system frequency drops below said lower frequency limit and said variable is within the range defined by the upper and lower thresholds, and means for switching on or increasing power supplied to the load when said frequency is above the upper frequency limit and said variable is within the range defined by the upper and lower thresholds.

3. An apparatus as claimed in claim 2 further comprising a sensing and analysis means adapted to automatically optimise or adjust the predetermined threshold values in response to recent recorded behaviour of the overall mains supply system.

4. An apparatus as claimed in any preceding claim further comprising means to provide a control signal to set the apparatus to an active or inactive mode.

5. An apparatus as claimed in claim 4 wherein the control signal is provided by an on/off switch

6. An apparatus as claimed in claim 4 wherein the control signal is provided by a control receiver which monitors and receives signals from a predefined radio signal.

7. An apparatus as claimed in any preceding claim further comprising means for monitoring an incoming radio frequency signal and comparing said incoming signal with a preloaded range of identifiers in order to individually identify said apparatus from a population of such devices.

8. An apparatus as claimed in claim 7 wherein said incoming signal is encrypted and wherein said apparatus comprises means for decoding said encrypted signal.

9. An apparatus as claimed in claim 7 wherein said incoming signal is used to turn the apparatus on or off.

10. An apparatus as claimed in claim 2 wherein the means for switching off or reducing power supply to the load, and said means for switching on or increasing power supplied to said load comprises means for providing a switch control signal.

11. An apparatus as claimed in claim 10 wherein said switch control signal is provided to an on/off switch.

12. An apparatus as claimed in claim 10 wherein said

switch control signal is provided by a device so as to vary said load continuously or in multiple discrete load steps.

13. An apparatus as claimed in claim 10,11 or 12 comprising an on/off latch to ensure that the last authorised switch control signal is retained and used.

14. An apparatus as claimed in claim 2, or any claim dependent thereon, wherein the apparatus includes means to set its thresholds with reference to a statistically random selection from a distribution of limits within a range.

15. An apparatus as claimed in claim 14 further comprising a plurality of random range selectors.

16. An apparatus as claimed in claim 2 wherein said means for detecting the frequency of mains power supplied to the system comprises means to produce a signal proportional to said measured frequency

17. An apparatus as claimed in claim 2 wherein said means for comparing said variable with said predetermined thresholds comprises a high frequency range detector to determine the range of frequencies, above the central frequency, over which the controller will operate; and a low frequency range detector to determine the range of frequencies, below the central frequencies, over which the controller will operate; and a high frequency limit selector which generates the control limits based on min/max frequency values and the random signal; and a high frequency limit detector to detect when high frequency limits have been exceeded; and a low frequency limit selector which generates the control limits based on the low frequency signal and the random signal; and a low frequency limit detector to

detect when the low frequency limits have been exceeded; and a means to receive control signals from the device which is to be controlled; and a sensor limit comparator which indicates when sensor limits have been exceeded; and a sensor set point control which is used to adjust the central point of the parameter around which the controller is to control; and a central frequency detector which produces a central frequency signal indicating the nominal frequency that the controller is aiming to support.

18. An apparatus as claimed in any preceding claim wherein the apparatus is in the form of a Programmable Logic Controller (PLC).

19. An apparatus as claimed in any preceding claim (excluding claim 18) wherein the apparatus is in the form of an Integrated Circuit (IC).

20. An apparatus as claimed in claim 14, or any claim dependent thereon, wherein the distribution of limits is set to cause a function of the system frequency over time to be an indicator of the overall balance of supply and demand across the system.

21. A method of responding to frequency variations in a power supply system comprising:

(A) monitoring the frequency of the system and comparing this with predetermined upper and lower frequency thresholds;

(B) monitoring a parameter of an electric load which consumes intermittent or variable electric energy in order to maintain said parameter within control limits;

(C) comparing said measured parameter with predetermined upper and lower parameter thresholds;and

(D) controlling the power consumed by said load

when said system frequency is outside of the range defined by said upper and lower frequency thresholds and said parameter is within the range defined by said upper and lower parameter thresholds.

22. A method as claimed in claim 21 further comprising setting the thresholds based on statistical variations.

23. A method as claimed in claim 22 wherein the switch on voltage of the apparatus is used to generate a random value for said statistical variations.

24 A method as claimed in claim 21, 22 or 23 wherein the central or nominal frequency of the supply is monitored to determine the closest standard supply frequency.

25. A method as claimed in claim 22 wherein variations in frequency are measured over given periods to provide statistical data for said statistical variations.

26. A method as claimed in claim 25 wherein the measurements are made over a period of days and compared to provide said statistical data.

27. A method as claimed in any of claims 21 to 26 wherein the monitoring of said parameter is by means of a sensor which can detect the parameter in question and provide a signal indicative of its value or level.

28. A method as claimed in any of claims 21 to 27 wherein said control of power consumed is by means of an on/off switch.

29. A method as claimed in any of claims 21 to 27 wherein said control of power consumed is provided by a device so as to vary said load continuously or in

multiple discrete load steps.

30. A method as claimed in any of claims 21 to 29 wherein the control of said power can be manually controlled.

31. A method as claimed in any of claims 21 to 30 wherein the control of said power is via radio signal.

32. A responsive load system substantially as herein described, with reference to Figures 1-4 of the accompanying drawings.

33. A method substantially as herein described, with reference to Figures 1-4 of the accompanying drawings.

25.

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Claims searched:	All	**Date of search:**	4 January 2001

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Databases searched:

UK Patent Office collections, including GB, EP, WO & US patent specifications, in:

UK Cl (Ed.S): H2H (HAD, HAQ, HAS, HSL)

Int Cl (Ed.7): H02H 7/06; H02J 3/12, 3/14; H02P 9/00, 9/02

Other: Online: EPODOC, JAPIO, WPI

Documents considered to be relevant:

Category	Identity of document and relevant passage		Relevant to claims
A	US 4385241	(PEDDIE et al.)	
Y	US 4345162	(HAMMER et al.) see whole document.	Y: 4-11,31
X, Y	US 4317049	(SCHWEPPE) see whole document, particularly col. 3, lines 5-44.	X: 1,2,16,21 at least Y: 4-11,31

X	Document indicating lack of novelty or inventive step	A	Document indicating technological background and/or state of the art.
Y	Document indicating lack of inventive step if combined with one or more other documents of same category.	P	Document published on or after the declared priority date but before the filing date of this invention.
&	Member of the same patent family	E	Patent document published on or after, but with priority date earlier than, the filing date of this application.